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Foliar Fertilization of Field Crops

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FOLIAR FERTILIZATION OF FIELD CROPS

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INTRODUCTION

The practice of supplying minerals to plants through their leaves is not new. For the past ten years foliar sprays containing iron, copper, zinc or manganese have been used with varying degrees of success to correct trace element deficiencies in plants. Recently, some experiments have been conducted which indicated that nitrogen and phosphorus applied to the leaves of plants are absorbed through the leaves and assimilated by the plant. Numerous studies of foliar-applied nitrogen, particularly with fruit trees, have been conducted in recent years but only a few studies of the effect of foliar fertilization with phosphorus and potash have been reported. Therefore, experiments with a complete foliar spray applied to several important Ohio field crops appeared to be justified. These studies were designed with emphasis on the use of foliar sprays as a supplement to, rather than a substitute for conventional fertilization practices.

REVIEW OF LITERATURE

Studies of the effect of foliar application of nitrogen to fruit trees (1, 6, 7, 8), indicated that the yield of apples was increased when the trees were sprayed with urea. In these studies the yield increases from foliar-applied nitrogen were comparable to those secured from an equivalent amount of nitrogen applied to the soil. The initial effects of urea sprays appeared more rapidly but were of shorter duration than the effects of an equal amount of soil-applied nitrogen. Unlike the apple, the stone fruits do not appear to respond to foliar-applied urea (12, 16, 11).

Reports of investigations in which nitrogen fertilizers were applied to the foliage of corn (5), wheat (14) and tomatoes (10) indicate that foliar fertilization is no more effective than an equivalent amount of nitrogen applied to the soil. The authors (5, 14) emphasize that because of injury resulting from the required large amounts of nitrogen applied to the foliage, soil application of nitrogen is more practicable.

Results of experiments which have been published on the use of phosphorus and potassium sprays for vegetable crops have been negative. Hemphill and Murneek (9) failed to increase yields of greenhouse tomatoes with sprays containing calcium, phosphorus, and potassium. Danielson (4) was unable to increase the yield of potatoes, tomatoes, snap beans and lima beans when he sprayed them at regular intervals with a 1-2-1 ratio fertilizer solution. Brasher **et al.** (3) conducted a study of the effect of foliar fertilization of vegetable crops over a four-year period and concluded that no nutrient spray program on any crop proved to be economically sound.

Several studies (13, 15, 3) demonstrated that although plants will respond to foliar-applied fertilizers these responses are likely to occur only when the soil is extremely deficient in the elements applied to the foliage. Under these conditions soil applications were more practicable.

MATERIALS AND METHODS

During the period from 1952 to 1954 complete foliar sprays containing nitrogen, phosphorus and potash were applied to corn, soybeans, alfalfa, sugar beets, oats, and wheat. All foliar sprays, except those for alfalfa, were applied with a portable hand sprayer equipped with a low gallonage Tee Jet nozzle. The alfalfa was sprayed with a Jeep mounted boom sprayer. A spray concentrate having a 5-10-5 analysis was prepared by mixing 6.67 pounds of potassium hydroxide, 6.67 pounds of urea, 8.5 pounds of phosphoric acid, and 10.0 pounds of diammonium phosphate with 68.6 pounds of distilled water. This concentrate was diluted with an appropriate amount of water before application. The rate of solution application varied from 15 to 100 gallons per acre, depending on the crop and its stage of development. Preliminary trials were made to determine the quantity of solution necessary to provide thorough coverage without serious loss by runoff. The total amount of nutrients applied per acre per application and the number of applications are reported.

Experimental techniques were varied with the crop grown and are summarized along with the results of the individual experiments.

RESULTS

Corn

The studies with corn are reported for 1952, 1953, and 1954. Foliar applications in 1952 were made at the rate of approximately 100 gallons of solution per acre applied at 60 pounds pressure. Application to corn during 1953 and 1954 were made at 30 pounds pressure and at a rate of 15 to 30 gallons of solution per acre depending on plant size. Experimental design for all years was a randomized block with four or more replications. Plot length in the experiment in which corn was grown on soils of varying fertility level was 40 feet (Table 3). All other experiments with corn employed plots 70 feet in length. Plots contained four rows spaced 42 inches apart; the two center rows were harvested for yield determinations.

In 1952 foliar applications were made to row-fertilized corn grown on high fertility soils and under favorable weather conditions. In this experiment (Table 1) there was no yield difference which was statistically significant.

TABLE 1.—Corn Yields as Affected by Foliar Applied Complete Liquid Fertilizers, Wooster, 1952

Treatment*	Bu/acre
1-2-1† lb/acre foliar applied when corn was 24 inches high	117
1-2-1 lb/acre foliar applied at 24 inch height and repeated at 40 inch height	122
None	119
L.S.D. $_{.05}$	N.S.

*All corn fertilized in row with 3-12-12 at the rate of 300 lbs. per acre.
†Pounds of N, P_2O_5, and K_2O, respectively.

The results of experiments conducted at Mahoning and Trumbull counties in 1953 indicate that none of the foliar sprays had a significant effect on corn yield when compared with the untreated check plot (Table 2). Unfavorable weather and a limiting number of corn plants per acre were responsible for the low yields in the Mahoning County experiment.

The experiment conducted at Wooster in 1953 (Table 3) was designed as a split plot with each treatment applied to corn grown on soils low, medium and high in both phosphorus and potassium.

The data in Table 3 indicate that none of the foliar sprays at any one of the three levels of fertility produced yields which were significantly greater than the untreated check plot; however, the application of 300 pounds per acre of 4-16-8 drilled with the corn at the time of planting produced yields which were 19.5 and 7.2 bushels per acre larger than the check plot yields at the low and medium levels of fertility, respectively. At the high level of fertility the yields produced by the nonfertilized check plots and the row-fertilized plots were not significantly different. These data are of particular significance for two reasons. First, they show that there is a negative interaction between row fertilizer and soil fertility level, with the largest yield increases from row

TABLE 2.—Corn Yields as Affected by Foliar Application of Complete Liquid Fertilizers, Mahoning and Trumbull Counties, 1953

Treatment	Bushels/acre	
	Mahoning Co.	Trumbull Co.
No foliar treatment; no row fertilizer	34.0	91.1
Row fertilizer only*	31.7	97.8
Row fertilizer plus foliar treatment of 1-2-1† lb/acre per application at 12 and 24 inch corn heights	32.8	91.4
Foliar treatment of 1-2-1 lb/acre per application at 12 and 24 inch corn height. No row fertilizer	31.1	86.6
Foliar treatment of 1-2-1 lb/acre per application at 6, 12, 24 and 36 inch heights. No row fertilizer	25.6	85.9
L.S.D. $_{.10}$	N.S.	7.3 bu.

*300 pounds per acre of 4-16-8.

†Pounds of N, P_2O_5 and K_2O, respectively.

fertilizer occurring at the low level of fertility and decreasing with an increase in soil fertility. Second, at the low-fertility level where conditions were most favorable for fertilizer response, foliar applications did not produce a significant yield increase.

TABLE 3.—Corn Yields as Affected by Row and Foliar Placement of Complete Fertilizer to Corn Grown on Soils of Varying Fertility Level, Wooster, 1953

Treatment	Fertility level		
	Low	Medium	High
	bu/acre	bu/acre	bu/acre
No foliar treatment; no row fertilizer..........	33.1	59.0	71.5
No foliar treatment. 300 lb/acre of 4-16-8 in row at planting	52.6	66.2	72.5
Foliar treatment of 1.4-2.8-1.4* lb/acre per application at 6 and 12 inch corn heights. .	38.8	60.8	74.0
Foliar treatment of 1.4-2.8-1.4 lb/acre per application at 6, 12, and 24 inci corn heights. .	33.1	58.7	69.7
Foliar treatment of 1.4-2.8-1.4 lb/acre per application at 6, 12, 24, and 36 inch corn heights	35.9	59.4	73.6

L.S.D. $_{.05}$ between treatment means for a given fertility level— 6.6 bu.

*Pounds of N, P_2O_5 and K_2O, respectively.

Sugar Beets

In 1954 a 1-2-1 ratio liquid fertilizer was applied to sugar beets grown on a Hoytville clay loam. Single and multiple sprays were applied to the beets at various stages of development. Each foliar treatment was used in combination with row-fertilized and nonfertilized beets. The time of application, number of applications, and the pounds of nitrogen, phosphoric acid and potash applied per application are reported in Table 4. Foliar applications were made at 30 pounds pressure and applied at the rate of approximately 15 gallons of solution per acre. The experimental design was a randomized split plot with four replications. Plots were 30 feet in length and contained four rows spaced 30 inches apart.

The data in Table 4 show there was no yield difference between any two foliar treatment means that was statistically significant; however, the mean yield of all treatments receiving row fertilizer was significantly greater than the mean yield of the nonfertilized beets. The data indicate that foliar fertilization, when used in the absence of conventional row fertilizers and as applied in this experiment, was not capable of producing optimum beet yields.

TABLE 4.—Sugar Beet Yields as Affected by Row and Foliar Applied Complete Liquid Fertilizers, Hoytville, 1954

Foliar Treatment*	Beet yields—Tons/acre		
	No row fertilizer	Row fertilized†	Foliar mean
One application of 1.4-2.8-1.4‡ lb/acre	20.5	23.9	22.2
Two applications of 1.4-2.8-1.4 lb/acre application	20.4	26.2	23.3
Three applications of 1.4-2.8-1.4 lb/acre application	21.3	23.6	22.5
Four applications of 1.4-2.8-1.4 lb/acre application	20.3	24.1	22.2
Row fertilizer mean	20.6	24.5	

L.S.D. $_{.05}$ Row fertilizer mean 1.5 T.

L.S.D. $_{.05}$ Foliar mean N.S.

*First application made when leaves were 6" long; succeeding applications at two week intervals.

†400 lb/acre of 4-16-16 in row at planting.

‡Pounds of N, P_2O_5 and K_2O, respectively.

TABLE 5.—Soybean Yield as Affected by Foliar Applied Complete Liquid Fertilizers, Wooster, 1953

Treatment	Bu/acre
No foliar treatment; no row treatment	9.8
No foliar treatment—200 lb/acre 5-10-10 applied in row at planting	10.0
Foliar treatment of 1-2-1* lb/acre applied at flowering—200 lb/acre 5-10-10 in row at planting	10.4
Foliar treatment of 1-2-1 lb/acre applied at flowering—no row fertilizer	10.5
L.S.D. $_{.05}$	N.S.

*Pounds of N. P_2O_5 and K_2O, respectively.

Soybeans

A 1-2-1 ratio liquid fertilizer was applied to soybeans with and without row fertilizers, as reported in Tables 5 and 6. The solutions were applied with a portable compression sprayer at 30 pounds pressure and at the rate of 20 gallons of solution per acre. The experiments at Wooster in 1953 and at Columbus in 1954 were of a randomized complete block design with four replications at Wooster and five at Columbus. The plots at Wooster were 90 feet long and contained four rows spaced 42 inches apart; the two center rows were harvested for yield determinations. The plots at Columbus were 240 feet long and contained three rows spaced 28 inches apart; the three rows were harvested for yield estimates. The data for 1953 in Tables 5 and 1954 in Table 6 show that neither row fertilizer nor foliar sprays alone or in combination produced a significant yield increase over the untreated check plot. Late planting and a severe mid-summer drought were responsible for the low yields in 1953.

TABLE 6.—Soybean Yield as Affected by Foliar Applied Complete Liquid Fertilizers, Columbus, 1954

Treatment	Bu/acre
No foliar treatment; no row fertilizer	32.1
No foliar treatment—250 lb/acre 0-20-20 applied in row at planting	30.0
Foliar treatment of 1-2-1* lb/acre applied to beans 12 inches high—250 lb/acre 0-20-20 in row at planting	33.3
Foliar treatment of 1-2-1 lbs. per acre applied to beans 12 inches high and repeated at bloom—250 lb/acre 0-20-20 in row at planting	31.5
L.S.D. $_{.05}$	N.S.

*Pounds of N, P_2O_5 and K_2O, respectively.

Alfalfa

In 1951 two rates of a 1-2-1 ratio liquid fertilizer were applied to an excellent stand of alfalfa ten days after the second cutting had been made. The solution was applied with a Jeep-mounted boom sprayer at the rate of 100 gallons per acre. The experimental design was a complete randomized block with six replications. Plots were 14 feet wide and 100 feet long. A seven-foot swath was cut from the entire length of the plot to determine the effect of foliar treatment on third-cutting alfalfa hay yields.

The data in Table 7 show that the application of fertilizer as a foliar spray did not produce yields which were significantly different from the unsprayed check plot.

TABLE 7.—Yield of Alfalfa Hay as Affected by Foliar Applied Complete Liquid Fertilizers, Wooster, 1951

Foliar Treatment		Pounds hay (20% H_2O)
None		1120
Foliar treatment of 1-2-* lb/acre		1060
Foliar treatment of 2.5-5.0-2.5 lb/acre		1100
	L.S.D. $_{.05}$	N.S.

*Pounds of N, P_2O_5 and K_2O, respectively.

Oats

Tests of the response of oats to foliar applications of a 1-2-1 ratio liquid fertilizer used as a supplement to conventional fertilizer application at planting were made in 1952 and 1954. In 1952 an unsprayed check plot was compared with oats which were sprayed once when the oats were six inches high, and with oats sprayed when they were approximately six and 12 inches high. Plots were 10 feet wide and 80 feet in length. The design was a randomized complete block with four replications. The solutions were applied at the rate of 50 gallons per acre.

The data in Table 8 show that none of the foliar sprays had a significant effect on oat yields.

Wheat

In 1952, experiments with foliar fertilization of wheat were similar in design and purpose to those conducted with oats. Three rates of a 1-2-1 ratio liquid fertilizer were sprayed on the foliage of the wheat on May 1 when the wheat was approximately 8 inches tall. Solutions were

TABLE 8.—Oat Yield as Affected by Foliar Applied Complete Liquid Fertilizer

Foliar Treatment*	Bu/acre	
	Wooster, 1952	Columbus, 1954
None	43.4	60.5
1-2-1† lb/acre foliar applied May 30	45.6	....
1-2-1 lb/acre foliar applied May 30; repeated June 15	44.5	....
1.5-3.0-1.5 lb/acre foliar applied May 18 and June 8	....	56.6
L.S.D. .05	N.S.	N.S.

*Oats in all treatments received 200 lb/acre of 3-12-12 applied at planting.

†Pounds of N, P_2O_5 and K_2O, respectively.

applied to the foliage with a wheelbarrow-type power sprayer at the rate of 135 gallons per acre. The experiment was designed as a complete randomized block with four replications. Individual plots were 40 feet long and 7 feet wide.

The data in Table 9 show that none of the nutrient sprays had a significant effect on wheat yield.

TABLE 9.—Wheat Yield as Affected by Foliar Applied Complete Liquid Fertilizers, Wooster, 1953

Foliar Treatment*	Bu/acre
No foliar treatment	34
1-2-1† lb/acre foliar applied	35
2-4-2 lb/acre foliar applied	35
3-6-3 lb/acre foliar applied	33
L.S.D. .05	N.S.

*All wheat received 3-12-12 at the rate of 300 lbs. per acre applied at planting.

†Pounds of N, P_2O_5 and K_2O, respectively.

DISCUSSION

The usefulness and limitations of foliar fertilization can be more fully appreciated when the mineral requirements of plants and the means of satisfying these requirements are considered. Because the requirement of field crop plants for the so-called trace or minor elements is relatively small these elements should lend themselves best to the foliar method of application. Sprays containing trace elements appear to be readily absorbed and one or two dilute sprays will provide effective control of several trace element deficiencies. Boynton (2) has recently reviewed the literature on nutrition by foliar application and has included numerous references to experiments showing the effectiveness of this method for correcting trace element deficiencies.

The probability of securing positive plant responses to foliar-applied nitrogen, phosphorus, and potassium are less promising, although these elements have been shown to be absorbed by leaves to which they are applied. The quantitative plant requirement for these elements is so much greater than those for trace elements that several sprays at maximum safe concentration are necessary to bring about the minimum responses considered necessary (5, 14, 10). Moreover, studies (2) indicate that response to foliar-fertilization is in proportion to a plant's deficiency in the element applied. Therefore, it is unlikely that field crops which are grown in soils having high levels of available nitrogen, phosphorus, and potassium will respond to supplemental foliar applications of these elements. On the other hand, crops grown in extremely deficient soil may be expected to respond to foliar fertilization, but because of the difficulty of supplying a large proportion of the nitrogen, phosphorus, and potassium via the leaves, it would still be necessary to resort to soil fertilization. This is illustrated by the data in Table 3 which show a significant increase in corn yields from soil fertilization but not from foliar application. At high-fertility levels even soil fertilization did not significantly increase the yield of corn. Just how deficient or infertile a soil must be before one can expect a significant response to foliar-applied phosphorus and potash has not been determined, but greenhouse experiments conducted at the Ohio Agricultural Experiment Station (15) and the data in Table 3 indicate that these levels are below those required for profitable production. Chief among the difficulties of supplying large amounts of minerals through the leaves is the necessity of making frequent and repeated applications of solutions sufficiently dilute to prevent burning. Unless frequent spraying is a regular part of the crop production program, the cost of application is prohibitive.

The efficiency of the leaves of various plants as organs for mineral absorption has not been established. That the leaves of some plants do absorb minerals has been established but the efficiency of absorption in terms of the proportion absorbed to that applied still remains in question. In solution culture studies (15) the application of phosphorus and potassium to corn leaves did not promote more growth than an equivalent amount of phosphorus and potassium added to the solution. Neither can it be safely assumed that the leaves of all plants are equally efficient absorbers of applied minerals. This is illustrated by the positive response of apples and the negative or doubtful response of peaches to foliar-applied nitrogen.

The data reported in this paper show that, under the conditions of this experiment, none of the field crops which received foliar-applied complete fertilizers responded to the treatment. It does not appear that the foliar application of proprietary mixtures of nutrients will be a useful supplement to sound conventional fertilization practices, nor does it appear that foliar fertilization of field crops will take the place of soil fertilization. In the final analysis it appears that the practice of foliar fertilization lends itself to the solution of special nutritional problems that cannot be solved by application of the fertilizer to the soil (2).

SUMMARY

During a three-year period complete foliar sprays containing nitrogen, phosphorus, and potash were applied to corn, oats, wheat, alfalfa, soybeans and sugar beets. The sprays were applied at various rates and stages of plant development as both a supplement to and a substitute for conventional applications of row fertilizers.

Under the conditions of these experiments none of the foliar spray programs produced a statistically significant yield increase. On infertile soils row fertilization of corn increased yields 16 bushels per acre; under the same conditions foliar application of fertilizer without row fertilizer did not significantly affect corn yields.

The results of this study with six important field crops show that the application of complete foliar sprays did not serve as an effective supplement to or as a substitute for conventional soil fertilization practices.